EFFECTS OF RAW COTTON NONCELLULOSIC CONTENT AND FIBER ROTORRING FRICTION ON YARN RING SPINNING PERFORMANCE

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ABSTRACT. *In the manufacturing of cotton textile goods, especially with modern high speed processing machinery, fiber noncellulosic surface related materials and naturally occurring metals may have significant effects on yarn spinning efficiency and product quality. Chemical and physical tests were conducted on cottons originating from five domestic growing areas to determine reducing sugars, wax, total noncellulosic extractable contents, individual residual metal contents, and frictional measurements to determine possible correlations between these properties and ring yarn spinning production performance. Adjusted skein−break factor, single yarn strength, and long thin place measurements were found to be highly related to fiber ethyl alcohol surface extractable materials and the total light metal content. Yarn yellowness (+b) was highly related to metal content. Process carding wastes correlated with increased raw fiber ash residues, potassium content, and the fiber−to−fiberfriction measurement.*

Keywords. *Cotton, Quality, Production, Performance, Noncellulosic, Extractions, Sugars, Waxes, Metals, Friction, Ring spinning, Adjusted skein break factor, Single yarn strength, Yellowness.*

Ring spinning has traditionally been a good predictor of the quality of cotton, because this method of processing is highly sensitive to lint imperfections and variations. Good yarn strength, uniformity in appearance and evenness, and few interruptions during spinning are the most desirable characteristics in spinning. A number of well−known non−fibrous materials such as trash, seed coat fragments, man−induced surface contaminants, insect sugars, and naturally occurring noncellulosic materials that are part of the fiber growing process may directly affect spinning performance (Perkins, 1971; Perkins and Bragg, 1977). Man−induced contaminants may come from excessive levels of greases and oils introduced from machinery used in the harvesting and ginning processes, and various chemicals applied to the cotton prior to harvesting such as herbicides, insecticides, and defoliants. Concentrations of plant and insect sugars that may cause stickiness in textile processing have been well documented (Hector and Hodkinson, 1989). The occurrence of high levels man−induced contaminants and excessively sticky cottons from sugars harvested cottons generally represent only a very small portion of the annual crop. In such cases, special handling of the cotton is required.

When properly cleaned and blended prior to spinning, cottons prepared for processing are generally relatively free of trash, seed coat fragments, excessive amounts of man−induced contaminants, and have manageable levels of sugars. However, cotton also contains other non−cellulosic materials such as plant waxes, varying amounts of ionic species (in the form of organic acids and low−molecular−weight oxides), and metals that are present throughout yarn spinning.

Raw cotton alcohol extractables (which include wax, small amounts of certain metals, and other non−fibrous materials) may vary from 10 to over 20 g/kg (1.0% to 2.0%) of the fiber weight (w.b). Extracted wax concentrations generally vary from 2 to 10 g/kg (0.2% to 1.0%) and concentrations of the most abundant metals (e.g. potassium, calcium, and magnesium) may vary from 2 to 7 g/kg (0.2% to 0.7%). Concentrations of total solvent extractable materials and residual metals are heavily dependent upon area of growth, variety, length of growing season, weathering history, and fiber maturity (Brushwood and Perkins, 1994). Because these materials are considered to be "surface related" and their combined concentrations may represent up to 30 g/kg (3.0%) of the fiber weight, wax, metals, and other noncellulosic materials may directly affect the way cotton performs in all stages of textile processing.

To date, very little work has been conducted or published documenting any influences wax, metals, and other noncellulosic materials on fiber may have on yarn processing efficiency. Hence, the purposes of this report are: (1) to compare the averaged ring spinning performance data for cottons from five domestic growing areas; (2) to determine the concentrations of reducing sugars, waxes, other extractable materials, residues from ashing, the light metal contents, and frictional properties of these same cottons; and (3) to determine their possible relationships with yarn ring spinning efficiency and performance.

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Experimental

Measurement of Raw Cotton Surface Properties and Metal Contents

A total of 12 raw cotton samples were selected from the bales that had previously been processed into yarn by ring spinning. This series of samples represented five domestic growing areas (two each from Arkansas, Georgia, Tennessee, and Texas, and four from Mississippi). All raw cottons were conditioned in a laboratory (24°C and 60% to 65% relative humidity) for at least three weeks before measuring fiber moisture content (triplicate measurements per sample). The standard deviation for the fiber moisture test is ±1.0 g/kg (0.10%). Moisture contents varied from 68 to 71 g/kg (6.8% to 7.1%) with no significant difference observed between growing areas. The average moisture content for all 12 cottons was 70 g/kg (7.0%). This percent was used in calculating the concentrations (d.b.) of all subsequent extractables and metal contents. Sugar contents were determined in triplicate by the USDA reducing sugar test (Perkins, 1971). The standard deviation for the sugar test is ±100 g/kg (10%) of the determined amount.

The waxes were removed from the lint by conducting 6−h Soxhlet extractions with 1−1−1 tri−chloroethane solvent. A single extraction consisted of the use of 100 mL of solvent to 2.50 g of sample. At least 15 extractions/cotton were conducted. After extraction, residual boiling flask solvent and extracted waxes were poured into a pre−weighed container. The solvent was evaporated from the container overnight in a 105°C oven, the container was sealed and removed from the oven, placed in a dessicator and allowed to cool to room temperature before re−weighing. The final wax content was calculated from averaging all 15 extractions. Total surface extractables (wax and other noncellulosic surface materials) were removed using the same Soxhlet extraction procedure as with wax removal, except the solvent used was absolute ethanol. The standard deviation for wax and alcohol extractions was ±30 g/kg (3%) of the amount determined.

Preparation and analysis of the cottons for metal content followed the procedure previously reported (Brushwood and Perkins, 1994). Triplicate 10 ± 0.005−g samples of raw cotton were ashed for 2.5 h at 650°C in a muffle oven. After ashing, the residues were weighed and the ash content was calculated for each sample. The ash residues were dissolved in 5 mL of concentrated hydrochloric acid (380 g/kg) and subsequently made up to 25 mL with de−ionized water. Dilutions were made depending upon the expected concentration of the metal in the sample and the predetermined linear operating range of the atomic absorption instrument used to determine metal content. These dilutions were 1250x for potassium, 625x for calcium and magnesium. At least two determinations were made on each solution and calculations of concentrations were based on a calibration curve using a minimum of four calibration standards at different concentrations and a blank (no ash). Hence, metal concentrations presented here represent average values for three determinations per cotton and at least two separate determinations per sample. The instrument used for analysis was a Model 200A Buck Scientific Atomic Absorption Spectrophotometer (East Norwalk, Conn.). All metals were measured using an air/acetylene flame while operating in the absorbance mode. Two µL of cesium chloride stock (3.1675 g of cesium chloride in 5 mL of de−ionized water) per mL of sample and calibration standard (1000 µg of cesium per mL of sample and calibration standard) were added to overcome any possible air/acetylene ionization of the potassium during analysis. Likewise, 2 µL of lanthanum chloride stock (6.684 g of lanthanum chloride per 5 mL of de−ionized water) per mL of sample and calibration standard (1000 µg of lanthanum per mL of sample and standard) were added when analysis for calcium and magnesium were conducted to overcome any possible depression of sensitivities to these metals by the presence of silicates, aluminum, or phosphates. The standard deviation for determination of metals was ±50 g/kg (5%).

Additional raw cotton samples were submitted to the Institute of Textile Technology (ITT) laboratory in Charlottesville, Virginia, for RotorRing fiber−to−metal (f/m) and fiber−to−fiber (f/f) frictional property measurements. These measurements determine the amount of energy (in J) to open parallel fibers formed on a rotor (Ghosh et. al., 1992). At least four measurements for both frictional tests were conducted per cotton. Data presented here represent average values for these frictional tests. High Volume Instrument (HVI) testing conducted by the USDA Quality Control Classing Office in Memphis, Tennessee determined fiber physical property measurements (micronaire, strength, color, etc.) for each bale. The Fiber Testing Laboratory at Clemson, South Carolina measured Suter−Webb short fiber contents.

Processing and Yarn Testing

The bales were divided into three lots of 45.4 kg (100 lb) each and randomly processed, using a total of 36 lots. The cotton was carded at 22.7 kg/h (50 lb/h) and ring spun (ring diameter of 42 mm) into 28/1 yarns at a standard 14,500−r/min spindle speed. Twist multiplier was 3.75 throughout for a total of 560 spindle hours of spinning per lot. Carding waste residues were determined. In addition to spinning performance ends down, each lot was tested for yarn single strand strength, yarn adjusted skein break factor, ILE (International Laboratory Equipment Tester) evenness neps and thick and thin places, and Classimat long thin and thick places. The significance of averages for data was determined by statistical variance of mean and t−tests. Correlation coefficients (r values) were based on linear regression.

Results and Discussion

Raw Cotton Measurements

Since it has been well established that area of growth has a significant impact on the amount of solvent removable surface materials, residues from ashing, and metal contents, it is necessary to look at these cottons from that prospective (Brushwood, 1992; Brushwood and Perkins, 1994). Although we were restricted to having only duplicate samples for four of the growing areas, these samples were thought to be good selections for our preliminary study due to the availability of good spinning data from processing multiple lots and because a variety of different growing locations were represented. HVI physical property tests and Suter−Webb short fiber contents for these cottons as averaged by growing area are listed in table 1. Micronaire averages were in a narrow range from a low of 3.79 for the Texas to a high of 4.62 for Tennessee grown cottons. Fiber strength measurements

Table 1. Average HVI and Suter−Webb short fiber contents of cottons from different domestic growing areas.

Location	HVI						Suter−Webb
	N	Fiber Micronaire	Strength (g/tex)	Rd	+b	Fiber Upper Half Mean (cm)	Uniformity Index	Short Fiber Content (g/kg)
Arkansas	2	4.10	25.92	77.0	9.9	2.72	0.813	130
Georgia	2	4.16	25.17	74.0	8.8	2.65	0.810	144
Mississippi	4	4.34	26.40	76.0	9.0	2.75	0.813	157
Tennessee	2	4.62	27.03	78.0	9.3	2.67	0.814	131
Texas	2	3.79	24.88	77.0	9.9	2.69	0.818	124

differed slightly from 24.88 (Texas) to 27.03 (Tennessee) g/tex. Individual bale HVI results showed a low of 23.70 g/tex (a Texas cotton) and a high of 27.98 g/tex (a Tennessee cotton). Color Rd measurements varied from a high of 78 to a low of 74. Fiber yellowness (+b) ranged from 8.8 for Georgia to 9.9 for Texas and Arkansas grown cottons. Upper half mean length ranged from 2.654 cm (1.045 in.) for Georgia to 2.703 cm (1.081 in.) for Mississippi grown cottons. Suter−Webb short fiber contents ranged from an average low of 124 g/kg (12.4%) for Texas to a high of 157 g/kg (15.7%) for the four Mississippi cottons. The average standard deviation for short fiber content was 19 g/kg (1.9%). Uniformity indexes ranged from 0.810 for Georgia to 0.818 for Texas cottons.

Table 2 is a summary of the reducing sugar concentrations, waxes, alcohol extractable materials, ash residues, potassium, total metal contents, and RotorRing frictional values for each respective growing area. Reducing sugar contents averaged from a low of 2.1 g/kg (0.21%) for Georgia cottons to 4.4 g/kg (0.44%) for Arkansas cottons. The highest individual sample sugar content measured was 4.8 g/kg (0.48%) and the low was 1.9 g/kg (0.19%). The error of determination for location averages was 7 g/kg (0.07%). Under normal processing conditions, these reducing sugar concentrations would not be expected to cause any stickiness problems in processing; especially in small lots where the potential for sticky sugars to build up on equipment is minimal. Surface wax concentrations averaged from a low of 3.7 g/kg (0.37%) for Tennessee cottons to a high of 5.3 g/kg (0.53%) for Arkansas cottons. Total alcohol surface extractions averaged from a low of 10.8 g/kg (1.08%) for Georgia cottons to 16.7 g/kg (1.67%) Arkansas cottons. Average area of growth error of determination for the wax was 0.2 g/kg (0.02%) and for the ethyl alcohol extractions was 2.2 g/kg (0.22%). Ash residues ranged from 10.6 g/kg (1.06%) for Georgia cottons to a high of 15.7 g/kg (1.57%) for the Arkansas cottons. The average error of determination for this test was 1.1 g/kg (0.11%).

Concentrations of potassium ranged from lows in Georgia and Mississippi cottons (3000 to 4000 ppm) to a high in Texas cottons (over 5000 ppm). The combined potassium, calcium, and magnesium metal concentrations were lower in Georgia and Mississippi cottons and higher in Texas and Arkansas cottons. Concentrations were typical of levels that were determined in domestic cottons in previous studies (Brushwood and Perkins, 1994). RotorRing frictional values ranged from 8093 to 9044 J for f/m and from 15851 to 18114 J for f/f friction measurements for the five different growing areas.

The reducing sugar content was found to correlate positively with the alcohol (total) surface extractables (r = 0.89), fiber Rd measurements (r = 0.96), ash residues (r = 0.81), and total light metal (potassium +calcium +magnesium) content (r = 0.77) but not significantly with fiber frictional properties or wax. Surface wax content correlated with fiber micronaire (r = −0.78). As micronaire decreased, fiber wax content increased. Fiber ash residues were positively related to the total light metal (K + Ca + Mg) content (r = 0.99). HVI yellowness (+b) also increased as the total fiber light metal content increased (r = 0.99), indicating the association of these materials with surface color.

Ring Spinning Performance Measurements

Averages for total carding waste, real ends down in processing down, calculated ends down (based on 1000 spindle hours), and yarn adjusted skein break factor in processing are given in table 3. Carding waste residues were in the narrow range of 61.4 to 64.2 g/kg (6.14% to 6.42%) for Georgia and Texas cottons, respectively. Calculated ends down averages ranged from a low of 17.5 for Arkansas to a high of 37.5 EDMSH (ends down per 1000 spindle hours) for Georgia cottons. Real ends down for the actual 560 spindle hours ranged from an average of 2.5 for Tennessee to 11.5 for Mississippi cottons. Yarn adjusted skein break factors ranged from 2036 to 2427 for Georgia and Arkansas cottons, respectively.

Table 4 is a summary of Statimat single strand strength and Evenness ILE (Industrial Laboratory Equipment Tester) measurements for neps and thin and thick places and Classimat long thin and thick places. Single strand strengths ranged from 13.47 (Georgia) to 16.02 g/kg for Arkansas

Table 2. Average raw cotton extractable materials, metals, and RotorRing friction measurements for different domestic growing areas.

Location	Extractables (g/kg)				Metals (ppm)		Friction (J)[a]	
	Sugar[b]	Wax	Total[c]	Ash (g/kg)	K	K+Ca+Mg	f/m	f/f
Arkansas	4.4	5.3	16.7	15.7	4810	6860	8093	16,517
Georgia	2.1	4.8	10.8	10.6	3360	4880	8339	15,851
Mississippi	3.3	4.3	15.7	12.5	3770	5390	9014	17,020
Tennessee	4.3	3.7	16.2	12.9	4040	5630	9044	16,904
Texas	3.9	4.8	14.1	15.5	5070	6720	8848	18,114

[a] RotorRing friction.
[b] Perkins reducing sugar test (Perkins, 1971).
[c] Alcohol extractables.

Table 3. Ring spinning processing data by growing area.

Location	Carding Wastes (g/kg)	Calculated EDMSH[a]	Real Ends Down[b]	Yarn Adjusted Skein Break Factor
Arkansas	62.0	17.5	6.8	2427
Georgia	61.4	37.5	7.2	2036
Mississippi	62.7	24.7	11.5	2279
Tennessee	62.3	19.0	2.5	2276
Texas	64.2	25.0	9.0	2159

[a] EDMSH is ends down per 1000 spindle hours.
[b] Ends down per 560 spindle hours.

cottons. Yarn evenness nep counts varied from 81 (Tennessee) to 115 per 914.4 m for Texas cottons, thick places from 315 (Arkansas) to 404 for Texas cottons, and thin places from 652 (Arkansas) to 802 for Texas cottons. Long thin place measurements ranged from 500 to over 1100, while long thick places were very low with counts for all area averaging less than 50.

Correlations Between Surface Extractables, Metal Contents, Fiber Friction, and Spinning Performance

Area of growth averages for chemical extractions, ash residues produced prior to determining metal contents, the potassium, the total of the light metals (potassium + calcium + magnesium), and fiber friction measurements were correlated to important yarn spinning data.

A positive correlation between RotorRing f/f frictions and carding waste residues was found (r = 0.99, fig. 1). These results may be a bit suspect due to the narrow ranges for both measurements. Future planned studies will justify or at least clarify any significance of this relationship. RotorRing frictional measurements (both f/m and f/f) did not correlate well with other ring spinning performance data.

As the amount of fiber alcohol surface extractables increased, yarn adjusted skein break factor (r = 0.94, fig. 2) and single strand strength (r = 0.89) also increased. Classimat yarn long thin place measurements decreased as alcohol extractables increased (r = −0.87, fig. 3). Since the sugar levels were positively related to total alcohol extractables, similar relationships between yarn adjusted skein break factor and single strand strength and the reducing sugar contents were seen. The only correlation between fiber wax and any spinning performance measurement was a tendency for yarn long thick places to decrease (r = −0.91) as wax concentrations increased.

Positive relationships were found between ash residues and carding waste (r = 0.60), yarn adjusted skein break factor (r = 0.62), and yarn single strand strength (r = 0.88, fig. 4). Increasing levels of the metal potassium correlated positively with increasing carding waste residues (r = 0.68) and increasing yarn single strand strength measurements (r = 0.78). Since potassium is the most predominant metal present, correlations between fiber total light metal content (combined potassium, calcium, and magnesium content) and carding waste residues and the yarn single strand strength measurements were similar to those obtained for the potassium content.

Table 4. Ring spun yarn Statimat single strand strength, ILE[a] evenness, and Classimat results for cottons from different U.S. growing areas – 28/1 ring yarns.

Location	Statimat Single Strand Strength (g/kg)	ILE Evenness		Classimat	
		Neps/ 914.4 m	Thick Places	Thin Places	Long Thin Places	Long Thick Places
Arkansas	16.02	85	315	652	512	2
Georgia	13.47	83	354	722	1109	4
Mississippi	14.79	107	377	739	803	11
Tennessee	14.93	81	352	720	805	41
Texas	15.00	115	404	802	993	7

[a] Industrial Laboratory Equipment Tester.

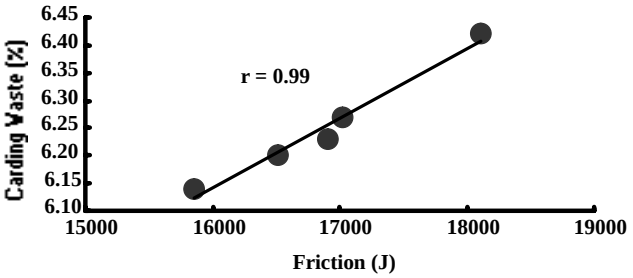

Figure 1. Relationship between fiber−to−fiber RotorRing friction and carding waste.

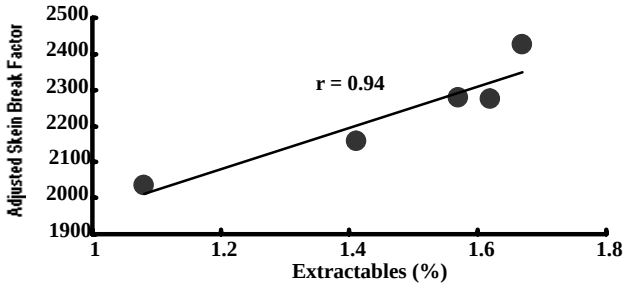

Figure 2. Relationship between ethyl alcohol extractables and yarn adjusted skein break factor.

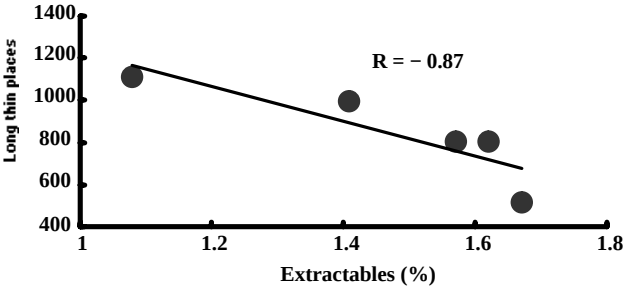

Figure 3. Relationship between ethyl alcohol extractions and yarn long thin places in ring spinning.

Summary and Conclusions

Multiple bales of cotton from five domestic growing areas were subjected to routine HVI fiber physical property measurements, Suter−Webb short fiber measurements, fiber RotorRing friction tests, chemical analysis for reducing sugars and wax contents, surface extractables, ash residues, and light metal contents. Each bale was divided into three separate lots and randomly ring spun into 28/1 yarn. Fiber chemical, physical property, and processing performance

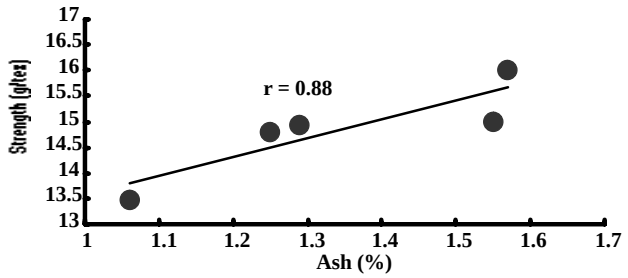

Figure 4. Relationship between fiber ash residues and ring yarn single strand strength.

results were averaged by growing area to determine possible relationships between noncellulosic content, fiber frictional properties, and processing efficiency and quality.

As the total ethyl alcohol surface extractables on the fiber increased, Classimat yarn long thin place measurements decreased. Increasing levels of total alcohol extractable materials also correlated with increases in yarn adjusted skein break factor and single strand strength measurements. There were no apparent correlations between alcohol extractables and f/m or f/f RotorRing friction. Yarn long thick places tended to decrease as the fiber wax content, which was micronaire−dependent, increased.

Fiber total light metal contents were seen to correlate positively with yarn single strand strength and the fiber yellowness (+b) measurement. As the light metal contents increased, yarn single strand strengths and fiber yellowness increased. Increasing levels of carding wastes correlated positively with increasing RotorRing f/f friction measurements.

This very limited survey of cottons from different domestic growing areas was basically designed to determine the potential for raw cotton surface waxes, metal contents, and other noncellulosic constituents, and frictional properties to influence yarn processing efficiency and quality. The limited preliminary results and conclusions in this report are subject to verification in current studies being conducted on a wider range of cottons with multiple replications. We also have plans to investigate the effects of noncellulosic materials and the role of individual metals on different yarn spinning systems. It is clear, however, that noncellulosic materials in varying levels on raw cottons can significantly affect fiber processing performance, appearance, and overall quality.

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